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Short Comunication

Safeguarding China's threatened cycads: Strategies to combat alarming habitat degradation and anthropogenic collection pressure

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Abstract

Cycads (*Cycas* L.) are ancient plants of immense ecological and evolutionary significance, yet they now face escalating threats to their survival. Around 20 cycad species remain in China, beset with highly restricted distributions and small, fragmented, declining and threatened populations. Despite strengthened legal protection and recent conservation efforts, these plants continue to suffer from habitat destruction and anthropogenic collection pressure. Infrastructure projects, including road construction and agricultural expansion, have fragmented and degraded critical cycad habitats. Concurrently, the rise of e-commerce platforms has facilitated unregulated online collection and trade, complicating enforcement. This manuscript addresses these challenges and proposes a comprehensive conservation strategy. They include enhancing habitat protection through establishing buffer zones, creating a community-based "Cycad Safeguarding Network" and using advanced information technologies, such as artificial intelligence and blockchain for precision monitoring and enforcement. Integrating modern scientific tools with an integrated conservation strategy can safeguard China's cycads and provide a model for protecting other threatened plant species globally.

Key words: Advanced information technology, anthropogenic collection pressure, habitat destruction, integrated conservation strategy, precision enforcement, threatened cycad species

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Introduction

Cycads (*Cycas* L.) represent one of Earth's most ancient lineages of extant seed plants, having persisted for over 300 million years since the Carboniferous Period (Tao et al. 2021). These remarkable gymnosperms serve as living fossils, offering crucial windows into plant evolution and survival despite multiple mass extinction events (Habib et al. 2021; Liu et al. 2022). Beyond their evolutionary significance, cycads play vital ecological roles in their native ecosystems. Their deep root systems contribute to soil stabilisation, while their vegetative structures provide critical habitat for specialised pollinators and numerous other species (Terry et al. 2012; Gutiérrez-García et al. 2019). In many regions, cycads

hold profound cultural significance, featuring prominently in traditional medicine, landscaping and local customs (Bonta et al. 2019).

Despite their resilience through geological time, cycads now face unprecedented challenges that threaten their survival (Stewart et al. 2023). Globally, approximately 70% of cycad species are classified as threatened (Mankga and Yessoufou 2017), making them one of the most imperilled major taxonomic groups. These ancient plants face a complex web of threats, including habitat fragmentation due to urbanisation and agricultural expansion, the intensifying impacts of climate change on their restricted habitats and anthropogenic collection pressure from various trade activities (Retief et al. 2015; Xi et al. 2022; Tobgay et al. 2023). The slow growth rate and long reproductive cycles of cycads make them particularly vulnerable to these pressures (Webb and Osborne 1989) as populations struggle to recover from disturbance.

In China, approximately 20 species of cycads remain in the wild (Xi et al. 2022). However, most are limited to narrow and disjointed ranges and exist in small, fragmented populations (Fig. 1). The survival of these native cycads is under significant threat from both external anthropogenic pressures and internal biological constraints. Their inherent characteristics make them particularly vulnerable to extinction (Mankga and Yessoufou 2017; Yessoufou et al. 2017). Amongst the external threats, habitat destruction and anthropogenic collection activities have become the most urgent challenges facing Chinese cycad populations (Zheng et al. 2017; Xi et al. 2022). Therefore, urgent attention and coordinated conservation efforts are essential to ensure the long-term survival of these irreplaceable species.

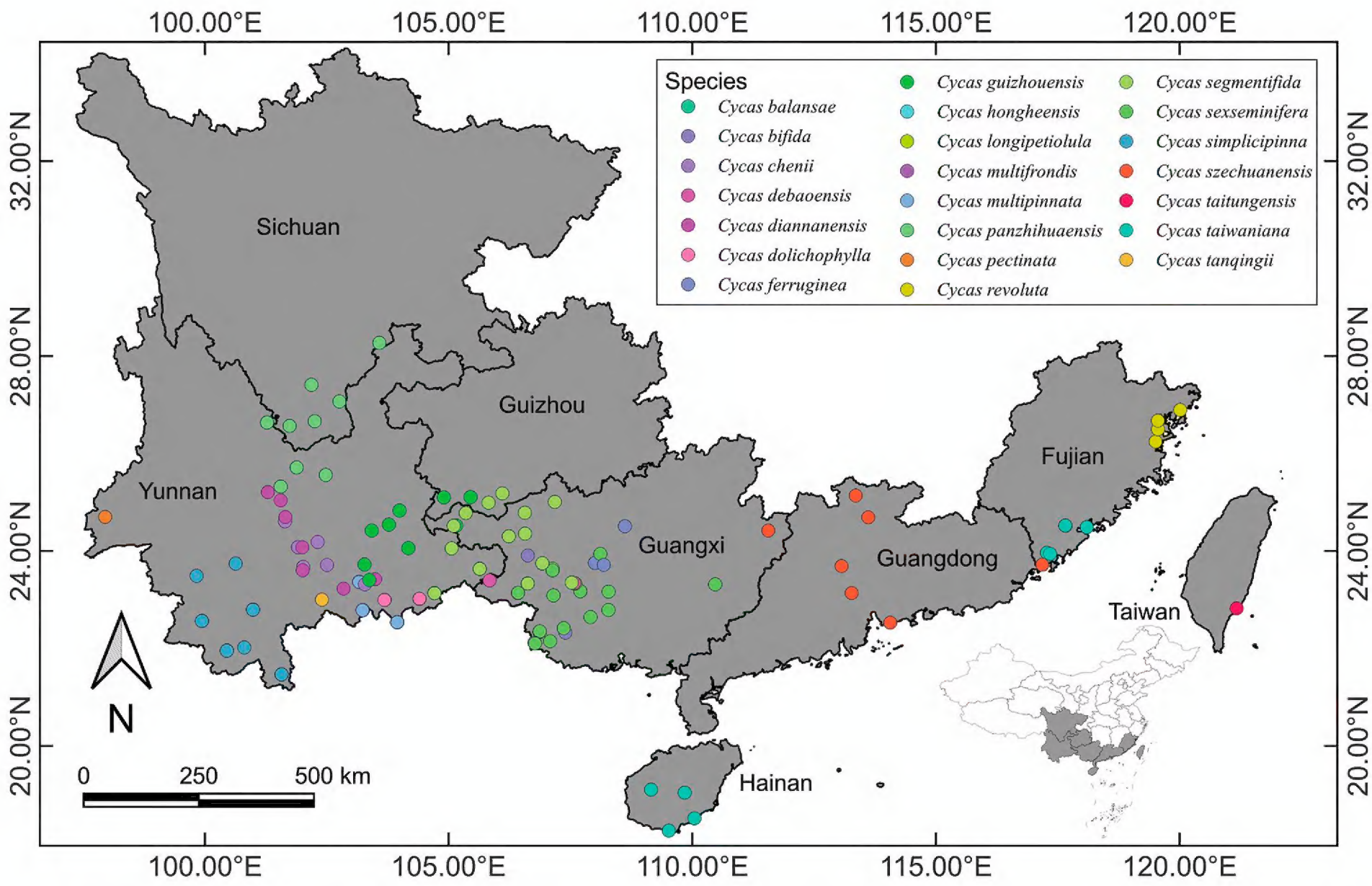

Figure 1. The distribution pattern of cycad species in China is primarily confined to restricted and disjointed ranges in the south-western and southern regions (data source: Xi et al. (2022).

Materials and methods

Data collection compliance

All data collection activities in this study were conducted in full compliance with Chinese laws and regulations. Field investigations were performed under permits issued by local forestry departments. Online monitoring was conducted using only publicly available information without engaging in any transactions. Population data were obtained through authorised research collaborations with protected area management authorities. All research activities followed the regulations governing the study of nationally protected plant species.

Field investigations

Field surveys were carried out across several regions in China where cycad populations are known to occur, focusing on areas experiencing infrastructure development and agricultural expansion. Survey sites included Hainan Jianfeng Mountain and other locations with documented cycad habitats.

During field investigations, we documented evidence of habitat destruction, fragmentation and conversion to alternative land uses. We recorded the presence and distribution of adult plants, saplings and seedlings at each site while assessing habitat conditions, including modifications due to infrastructure development (road networks, hydropower facilities) and agricultural conversion (commercial plantations, farmlands). All observations were photographically documented, with special attention to examples of habitat alteration and remaining cycad specimens. Based on these observations, we evaluated the potential for natural regeneration in affected populations, considering factors such as isolation, fragmentation and the presence of dispersal vectors.

Online trade monitoring

To assess the extent of illegal trade in Chinese cycads, we systematically monitored e-commerce platforms and social media channels from 2022 to 2024. Our monitoring protocol included regular searches across multiple online platforms using keywords related to cycad species and variants of their common names. This monitoring allowed us to identify patterns in the online cycad trade and compare these patterns with known conservation concerns for specific species, revealing potential hotspots of collection pressure on wild populations.

Conservation status assessment

We compiled conservation status information from multiple sources to comprehensively understand the threat level facing Chinese cycad species. This compilation included data from the IUCN Red List of Threatened Plants (Cycad Specialist Group 2024), national protection status under Chinese legislation – particularly the 2020 update listing all *Cycas* species as national first-class key protected plants (Zheng et al. 2017) – and Plant Species with Extremely Small Populations (PSESP) designations (Ma et al. 2013). Additionally, we reviewed existing scientific literature regarding population dynamics, genetic diversity and extinction risk factors specific to Chinese cycad species. The literature en-

abled us to contextualise our field observations within the broader understanding of cycad conservation biology and to identify critical knowledge gaps.

Special attention was given to comparative analysis with global cycad conservation cases, including parallel situations in South Africa involving Encephalartos populations (Stewart et al. 2023) and illegal trade patterns documented worldwide. This comparative approach allowed us to identify both unique challenges facing Chinese cycad species and potential conservation solutions that have proven effective in similar contexts globally.

Based on these analyses, we developed specific recommendations for habitat protection, community engagement and illegal trade prevention, emphasising practical implementation within the Chinese conservation policy framework. All field investigations were conducted with appropriate permits from relevant authorities. No specimens were collected during our research and care was taken to minimise disturbance to cycad populations and their habitats. The monitoring of online trade was performed using publicly available information and no transactions were initiated as part of this research.

Results and discussion

External threats to cycads in China

Over the past decades, China has significantly strengthened its commitment to cycad conservation by establishing protected areas and conservation sites (Chen and Liu 2004; Xi et al. 2022). All species of the genus *Cycas* are now listed as national first-class key protected plants from 2020, receiving the highest level of legal protection (Zheng et al. 2017). The IUCN Red List of Threatened Plants has designated about two-thirds of the world's extant cycad species as threatened (Cycad Specialist Group 2024). Almost all of China's cycad species have been listed as threatened or near threatened and some species have been classified as Plant Species with Extremely Small Populations (PSESP) (Ma et al. 2013). The limited genetic diversity of isolated subpopulations may accentuate the vulnerability to local extinction.

Despite various scientific designations and legislative safeguards, habitat destruction continues sporadically, particularly through infrastructure development and land-use changes (Xiao et al. 2020). Field investigations reveal that major infrastructure projects, including road networks and hydropower facilities, have directly destroyed or fragmented several cycad populations, especially in mountainous regions where many endemic species occur. Large-scale infrastructure projects, in conjunction with their collateral impact envelope, can potentially wipe out a notable portion of a species range. For instance, the construction of the hydropower station in Hainan Jianfeng Mountain has impacted local *Cycas* populations. This development mirrors similar cases worldwide, such as the habitat destruction of *Encephalartos* populations in South Africa due to artificial interference (Stewart et al. 2023).

Agricultural expansion has further exacerbated habitat loss, with traditional cycad habitats converted into commercial plantations and farmlands (Fig. 2). The habitat destruction eliminates existing plants and growth conditions. It disrupts critical ecological processes, including pollinator relationships and natural recruitment patterns (Terry et al. 2012). The cumulative effect of these

Figure 2. Cycad habitat impacted by orchard cultivation. **A.** Mango tree planted in the orchard; **B.** Cycad seedlings remaining at the orchard's edge; **C.** Resprouted cycad after cutting; **D.** Adult cycad plant still surviving at the orchard's edge, indicating that the site was a suitable habitat for the species.

activities can fragment an original species range into multiple small isolated subpopulations, reducing genetic diversity and exchange and threatening long-term population viability.

The relatively large and heavy cycad seeds with limited dispersal distance (Dehgan and Yuen 1983; Hall and Walter 2013) can trap the remnant plants in dismembered and disjointed pockets. Vertebrate dispersers may be unable to traverse the wide distance and stressful conditions between pockets. Moreover, habitat degradation or destruction will likely stifle or eliminate the cycads' companion biotic dispersers. Therefore, the natural regeneration ability of the isolated subpopulations can be critically compromised. In addition, the excessive collection of cycad seeds for horticultural purposes can diminish the living seed bank and aggravate the reproductive decline of the contracted and dispersed ranges.

The rise of e-commerce platforms has dramatically accelerated the unregulated collection and trade in Chinese cycads (Fig. 3), creating unprecedented challenges for conservation. Online marketplaces have become the primary channel for the unregulated trade of these protected species, with sellers using sophisticated methods to avoid conservation monitoring (Lavorgna and Sajeva 2021). Our monitoring reveals an alarming volume of cycad specimens advertised online, often marketed as "rare collections", collected from wild populations or disguised as legally sourced plants. This pattern reflects global trends, similar to the surge in the unregulated collection activities of South African cycads through social media platforms (Williamson et al. 2016; Torgersen 2017).

The ease of online transactions has enabled collectors to efficiently connect with buyers (Perdue 2021), increasing sales and, hence, collection pressure on wild populations. Particularly concerning is the preference for mature specimens (Fig. 3A–C, F, H–J), which can fetch higher prices, but are also the most valuable

Figure 3. Cycads offered for sale online in China. **A, C, F, H, I.** Adult individuals; **D, K, J.** Saplings and seedlings; **E.** Germinated seed; **G.** Seeds. Most sellers claimed in their product descriptions that the plants were wild-collected.

for population survival. This targeted removal of reproductive adults has devastating consequences for population dynamics, as cycads' slow growth rates mean that replacing these individuals can take decades. Seed and seedling harvesting (Fig. 3D, G, K) can also eliminate the chances of natural regeneration.

Conservation priorities and suggested actions

Based on the survey of the alarming plight of natural cycad populations and their expanding online trading of mature plants and plant parts, preventative and protective measures are urgently required to contain the increasing pull factor on plant collection:

1. Strengthening protection. Protecting cycad habitats requires a multi-tiered and integrated approach, centred on ecosystem-level conservation. Priority should be given to establishing buffer zones around existing cycad populations to provide an assured cordon around the core ranges against perturbations (Tobgay et al. 2023), particularly in areas where infrastructure development is planned. These buffer zones should extend at least 1 km beyond known populations to maintain ecological connectivity and pro-

tect pollinator communities (Oliveira et al. 2020). To ensure effectiveness, environmental impact assessments must specifically include cycad population assessments before any infrastructure projects are approved in potential cycad habitats. A national cycad habitat restoration programme should also be initiated, focusing on degraded sites with historical cycad populations (Chen and Liu 2004; Huang 2011; Zheng et al. 2017). This programme should prioritise the restoration of native vegetation communities that support cycad recruitment and establishment.

2. Engaging local communities. This approach is crucial for sustainable habitat protection. Local communities should be empowered by establishing a "Cycad Safeguarding Network" – a society-based organisation that provides economic incentives for habitat protection, while building local capacity for conservation. These networks can integrate traditional ecological knowledge with scientific monitoring protocols (Kühl et al. 2020), creating sustainable livelihoods through activities, such as cycad population monitoring, habitat restoration and authorised seed collection for legitimate propagation programmes (Kumar et al. 2023). A sense of ownership can be nurtured to ensure villagers take pride in protecting their precious local resources. Success has been demonstrated in similar programmes for other endangered plants, such as community-based conservation projects in Indonesia (Damastuti et al. 2022).
3. Monitoring anthropogenic collection activities. Monitoring anthropogenic collection activities requires advanced information technology to track unregulated collection, trade networks and operations. A specialised conservation monitoring unit utilising predictive analytics and artificial intelligence should be established (Berk 2021; Haley and Burrell 2025), focusing specifically on monitoring online collection and trade activities (Lavorgna 2014). This unit should employ advanced image recognition algorithms to automatically detect cycad listings across multiple platforms, enabling rapid and pinpointed responses to unregulated collection activities (Lavorgna et al. 2020). Given the success of similar technologies in combating the illegal trade of pangolin scales (Cardoso et al. 2023), these tools could be readily adapted for cycad protection.

Conservation monitoring of cycad trade should be strengthened by implementing a digital tracking system that combines DNA barcoding with blockchain technology (Williamson et al. 2016). Each authorised cycad plant or plant part should be assigned a unique digital identifier linked to its genetic profile and chain of custody information. This system would allow instant verification of legal specimens, while making it more difficult to launder illegally-collected plants into legitimate markets. Similar systems have proven effective in timber tracking and could be adapted for the cycad trade (Lowe and Cross 2011), with particular attention to high-risk species and trade hotspots.

In addition to the key conservation measures discussed above, we recommend incorporating the following complementary strategies into a broader protection framework: establishing a national cycad conservation coordination mechanism involving forestry departments, research institutions, customs and law enforcement to enhance policy coherence and information sharing; strengthening public education through outreach to communities, enthusiasts

and policy-makers, along with school-based environmental programmes; deepening international cooperation by actively participating in CITES enforcement and sharing governance experience with relevant countries; and promoting artificial propagation and legal nursery operations to sustainably meet market demand and reduce pressure on wild populations. These integrated actions can further strengthen China's cycad conservation outcomes.

Conclusion

Preserving China's cycads represents a critical test of the country's ability to protect ancient biotic lineages in the face of modern and worsening challenges. While recent decades have seen improved legal protection and conservation measures for these living fossils, the persistent threats of habitat destruction and anthropogenic collection pressure demand enhanced, science-based responses. Such recent developments are ominous and augur ill for the survival of the precious and threatened cycad species. The complexity of these challenges requires a coordinated approach that operates at multiple scales, from local habitat protection to international trade enforcement. The preservation of cycads must be viewed not merely as a conservation challenge, but as an opportunity to demonstrate how science, technology, policy and community engagement can combine to protect Earth's botanical heritage. Today's actions to protect these ancient plants will determine whether future generations inherit viable populations of these remarkable species or merely their fossils and memories. The time for implementing comprehensive, evidence-based and science-guided conservation strategies is now.

Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

Use of AI

No use of AI was reported.

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Author contributions

C.X. conceived and wrote the original draft; C.Y.J. reviewed and edited the manuscript.

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Data availability

All of the data that support the findings of this study are available in the main text.

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